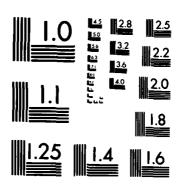
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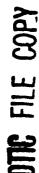
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Abstracts		
Document Control Data		
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TABLE OF CONTENTS

	Page
LIST OF REPORTS	1
AUTHOR INDEX	5
CONTRACTOR REPORT INDEX	8
SUBJECT INDEX	9
AD NUMBERS	18
ARSTDACTSDEPORT DOCUMENTATION PAGE (DD FORM 1473)	21

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TECHNICAL REPORTS 1984

REPORT NUMBER	TITLE	AUTHOR	DATE
ARLCB-TR-84001	Stress Distribution in a Cylindrical Bar Subjected to Cyclic Torsional Loading	P.C.T. Chen H.C. Wu	Jan 84
ARLCB-TR-84002	A Method of Analyzing Perforated Muzzle Brake Performance	CPT R.E. Dillon, Jr. H.T. Nagamatsu	Feb 84
ARLCB-TR-84003	Evaluation of Manganese Phosphate Coatings	R.A. Farrara	Feb 84
ARLCB-TR-84004	An Experimental Study of Perforated Muzzle Brakes	CPT R.E. Dillon, Jr. H.T. Nagamatsu	Feb 84
ARLCB-TR-84005	A Material Model for Reverse Yielding and Its Application to Torsion	P.C.T. Chen	Mar 84
ARLCB-MR-84006	Observations on the Aus-Quenching of Gun Steel and Related Properties	C.J. Nolan	Mar 84
ARLCB-TR-84007	Thermal and Transformation Stresses in Hollow Tubes During the Quenching Process	J.D. Vasilakis	Mar 84
ARLCB-TR-84008	On the Extremum of Bilinear Functional for Hyperbolic Type Partial Differential Equations	C.N. Shen	Apr 84
ARLCB-TR-84009	J-R Curve Determination Using Precracked Charpy Specimens and the Load-Drop Method for Crack Growth Measurements	J.A. Kapp	Apr 84
ARLCB-CR-84010	Improved Conventional Armament System Autoloader	D.E. Jones (BWL POC)	Apr 84
ARLCB-CR-84011	Conceptual Autoloader Design Study for Future Armament System for Combat Vehicles (FASCV)	B.D. Goodell M.W. Osborne R.A. Dahl R.V. Hettwer R.C.H. Schmidt D.E. Jones (BWL POC)	Apr 84

TECHNICAL REPORTS 1984 (CONT.)

REPORT NUMBER	TITLE	AUTHOR	DATE
ARLCB-CR-84012	Conceptual Design for 120mm Improved Conventional Armament System (ICAS) Autoloader	J.E. Wildman D.E. Jones (BWL POC)	Apr 84
ARLCB-MR-84013	Cadmium Plating vs. Other Coatings to Prevent Corrosion	R.A. Farrara	Apr 84
ARLCB-SP-84014	The Propellant Combustor Performance Tester	A.R. Graham	May 84
ARLCB-TR-84015	A Parametric Study of Perforated Muzzle Brakes	CPT R.E. Dillon, Jr.	May 84
ARLCB-TR-84016	Longitudinal Vibrations of Rods of Finite Length with Radial Deformation	J.J. Wu W.H. Chen	May 84
ARLCB-TR-84017	Embrittlement of 4340 Type Steel by Liquid Lead and Antimony and Lead-Antimony Solutions	M.H. Kamdar	May 84
ARLCB-TR-84018	Residual Stress Measurement in Circular Steel Cylinder	J. Frankel W. Scholz G. Capsimalis W. Korman	May 84
ARLCB-TR-84019	The Bauschinger and Hardening Effects on Residual Stresses in an Autofrettaged Thick-Walled Cylinder	P.C.T. Chen	Jun 84
ARLCB-TR-84020	Wall Thickness and Vent Area Effects on Perforated Muzzle Brake Performance	CPT R.E. Dillon, Jr.	Jun 84
ARLCB-TR-84021	Stress Intensity Factors for a Circular Ring with Uniform Array of Radial Cracks of Unequal Depth	S.L. Pu	Jun 84
ARLCB-TR-84022	Embrittlement of Gun Steel by Copper	R.M. Fisher A. Szirmae M.H. Kamdar	Jun 84
ARLCB-TR-84023	A Simple, Fracture Mechanics Based Method for Fatigue Life Prediction in Thick-Walled Cylinders	D.P. Kendall	Jul 84

TECHNICAL REPORTS 1984 (CONT.)

REPORT NUMBER	TITLE	AUTHOR	DATE
ARLCB-SP-84024	Index to Benet Weapons Laboratory (LCWSL) Technical Reports - 1983	R.D. Neifeld	Ju1 84
ARLCB-TR-84025	Wide Range Displacement Expressions for Standard Fracture Mechanics Specimens	J.A. Kapp G.S. Leger B. Gross	Jul 84
ARLCB-TR-84026	Hydrostatic Extrusion and Mechanical Properties of Tungsten Alloy Penetrators	C.J. Nolan M.H. Kamdar	Aug 84
ARLCB-TR-84027	Computer Aided Process Planning of Machined Metal Parts	CPT W.W. Olson	Sep 84
ARLCB-TR-84028	Secondary Waves from Nozzle Blast	G.C. Carofano	Oct 84
ARLCB-TR-84029	Blast Computation Using Harten's Total Variation Diminishing Scheme	G.C. Carofano	Oct 84
ARLCB-TR-84030	Electrical Resistivity in Low Resistivity Amorphous Alloys	L.V. Meisel P.J. Cote	Sep 84
ARLCB-TR-84031	Application of the Diffraction Model to Amorphous Magnesium Zinc Alloys	P.J. Cote L.V. Meisel	Sep 84
ARLCB-TR-84032	Effect of Interconnection of the Ends of a Sliding Bearing on Film Thickness	R.S. Montgomery	Sep 84
ARLCB-TR-84033	Autonomous Navigation for Mobile Robot Vehicles Over Hilly Terrain Using Rangefinding Measurements	C.N. Shen	Oct 84
ARLCB-CR-84034	Stress Corrosion Cracking Behavior of Tungsten Heavy Alloys	JG. Chung D.J. Duquette J.A. Kapp (BWL POC)	Oct 84
ARLCB-MR-84035	Compliance of a Three-Point Bend Specimen at Load Line	F.M. Haggag J.H. Underwood	Oct 84
ARLCB-TR-84036	Second Variations for the Stress Wave Problem Using the Euler- Lagrange and Adjoint Formulations	C.N. Shen	Oct 84

T,

TECHNICAL REPORTS 1984 (CONT.)

REPORT NUMBER	TITLE	<u>AUTHOR</u>	DATE
ARLCB-TR-84037	Stress Concentration Due to Axial Tension of Loaded Nonsymmetric- Shaped Grooves	Y.F. Cheng	Nov 84
ARLCB-TR-84038	Studies of Hydrostatic Coextrusion of Depleted Uranium-0.75 Titanium Alloy Reinforced with Tungsten Filament (A Progress Report)	I. AhmadR.J. FiorentinoE.G. Smith, Jr.J. Barranco	Nov 84
ARLCB-TR-84039	Fatigue Effects of M4A2 Zone 7 Round on 155 mm M185 Howitzer Tube Life	B.B. Brown	Dec 84
ARLCB-TR-84040	Tekedit - An Enhanced Editor for Direct View Storage Tube (DVST) Graphics Display Devices	M. Johnson	Nov 84
ARLCB-TR-84041	Characterization of Bore Surface Layers in Gum Barrels	M.H. Kamdar J.D. Venables	Dec 84
ARLCB-TR-84042	The Development of a Large Composite Anode for Plating Gun Tubes	G. D'Andrea R. Murray	Dec 84

AUTHOR INDEX--1984

AUTHOR	REPORT NUMBER
Ahmad, I.	ARLCB-TR-84038
Barranco, J.	ARLCB-TR-84038
Brown, B. B.	ARLCB-TR-84039
Capsimalis, G.	ARLCB-TR-84018
Carofano, G. C.	ARLCB-TR-84028 ARLCB-TR-84029
Chen, P. C. T.	ARLCB-TR-84001 ARLCB-TR-84005 ARLCB-TR-84019
Chen, W. H.	ARLCB-TR-84016
Cheng, Y. F.	ARLCB-TR-84037
Chung, JG.	ARLCB-CR-84034
Cote, P. J.	ARLCB-TR-84030 ARLCB-TR-84031
Dahl, R. A.	ARLCB-CR-84011
D'Andrea, G.	ARLCB-TR-84042
Dillon, R. E., Jr., CPT	ARLCB-TR-84002 ARLCB-TR-84004 ARLCB-TR-84015 ARLCB-TR-84020
Duquette, D. J.	ARLCB-CR-84034
Farrara, R. A.	ARLCB-TR-84003 ARLCB-MR-84013
Fiorentino, R. J.	ARLCB-TR-84038
Fisher, R. M.	ARLCB-TR-84022
Frankel, J.	ARLCB-TR-84018
Goodell, B. D.	ARLCB-CR-84011
Graham, A. R.	ARLCB-SP-84014

AUTHOR INDEX--1984 (CONT.)

AUTHOR	REPORT NUMBER
Gross, B.	ARLCB-TR-84025
Haggag, F. M.	ARLCB-MR-84035
Hettwer, R. V.	ARLCB-CR-84011
Johnson, M.	ARLCB-TR-84040
Jones, D. E.	ARLCB-CR-84010 ARLCB-CR-84011 ARLCB-CR-84012
Kamdar, M. H.	ARLCB-TR-84017 ARLCB-TR-84022 ARLCP-TR-84026 ARLCB-TR-84041
Kapp, J. A.	ARLCB-TR-84009 ARLCB-TR-84025 ARLCB-CR-84034
Kendall, D. P.	ARLCB-TR-84023
Korman, W.	ARLCB-TR-84018
Leger, G. S.	ARLCB-TR-84025
Meisel, L. V.	ARLCB-TR-84030 ARLCB-TR-84031
Montgomery, R. S.	ARLCB-TR-84032
Murray, R.	ARLCB-TR-84042
Nagamatsu, H. T.	ARLCB-TR-84002 ARLCB-TR-84004
Neifeld, R. D.	ARLCB-SP-84024
Nolan, C. J.	ARLCB-MR-84006 ARLCB-TR-84026
Olson, W. W., CPT	ARLCB-TR-84027
Osborne, M. W.	ARLCB-CR-84011
Pu, S. L.	ARLCB-TR-84021

AUTHOR INDEX--1984 (CONT.)

AUTHOR	REPORT NUMBER
Schmidt, R. C. H.	ARLCB-CR-84011
Scholz, W.	ARLCB-TR-84018
Shen, C. N.	ARLCB-TR-84008 ARLCB-TR-84033 ARLCB-TR-84036
Smith, E. G., Jr.	ARLCB-TR-84038
Szirmae, A.	ARLCB-TR-84022
Underwood, J. H.	ARLCB-MR-84035
Vasilakis, J. D.	ARLCB-TR-84007
Venables, J. D.	ARLCB-TR-84041
Wildman, J. E.	ARLCB-CR-84012
Wu, H. C.	ARLCB-TR-84001
Wu, J. J.	ARLCB-TR-84016

CONTRACTOR REPORT INDEX

CORPORATE AUTHOR	REPORT NUMBER
ARES, Inc. Port Clinton, OH	ARLCB-CR-84012
Emerson Electric Company St. Louis, MO	ARLCB-CR-84010
FMC Corporation Minneapolis, MN	ARLCB-CR-84011
Rensselaer Polytechnic Institute Troy, NY	ARLCB-CR-84034

SUBJECT INDEX--1984

SUBJECT	REPORT NUMBER
Abstracts	ARLCB-SP-84024
ADINA Computer Program	ARLCB-TR-84007
Adjoint Variables	ARLCB-TR-84036
Ammunition, Separated	ARLCB-CR-84010 ARLCB-CR-84011 ARLCB-CR-84012
Amorphous Materials	ARLCB-TR-84030 ARLCB-TR-84031
Anodes	ARLCB-TR-84042
Antimony	ARLCB-TR-84017
Approximate Theory	ARLCB-TR-84016
Autofrettage	ARLCB-TR-84019
Autoloaders	ARLCB-CR-84010 ARLCB-CR-84011 ARLCB-CR-84012
Autonomous Navigation	ARLCB-TR-84033
Ballistic Efficiency	ARLCB-TR-84020
Ballistic Tests	ARLCB-TR-84038
Bauschinger Effect	ARLCB-TR-84005 ARLCB-TR-84019 ARLCB-TR-84023
Beam Equations	ARLCB-TR-84008
Bend Specimens	ARLCB-MR-84035
Bibliographies	ARLCB-SP-84024
Bilinear Forms	ARLCB-TR-84008 ARLCB-TR-84036

SUBJECT ,	REPORT NUMBER
Blast	ARLCB-TR-84002 ARLCB-TR-84004 ARLCB-TR-84015 ARLCB-TR-84020 ARLCB-TR-84028 ARLCB-TR-84029
Burning Rate	ARLCB-SP-84014
Cadmium	ARLCB-MR-84013
Cannon	ARLCB-TR-84039
Characteristic Exhaust Velocity	ARLCB-SP-84014
Charpy Impact Tests	ARLCB-TR-84009
Coatings	ARLCB-MR-84013
Combustion Chambers	ARLCB-SP-84014
Compliance	ARLCB-MR-84035
Composite Materials	ARLCB-TR-84038 ARLCB-TR-84042
Computer Aided Process Planning	ARLCB-TR-84027
Computer Graphics	ARLCB-TR-84040
Copper	ARLCB-TR-84022
Corrosion Resistance	ARLCB-TR-84003 ARLCB-MR-84013
Crack Propagation	ARLCB-TR-84009 ARLCB-TR-84022
Cracking (Fracturing)	ARLCB-CR-84034
Cracks	ARLCB-TR-84021
Cyclic Loading	ARLCB-TR-84001
Cylindrical Bodies	ARLCB-TR-84001 ARLCB-TR-84018 ARLCB-TR-84021

SUBJECT	REPORT NUMBER
Depleted Uranium	ARLCB-TR-84038
Diffraction Models	ARLCB-TR-84030 ARLCB-TR-84031
Direct View Storage Tubes (DVST)	ARLCB-TR-84040
Displacement	ARLCB-TR-84025
Editing	ARLCB-TR-84040
Eigenvalue Problems	ARLCB-TR-84016
Electrical Resistance	ARLCB-TR-84030
Electron Transport	ARLCB-TR-84030 ARLCB-TR-84031
Embrittlement	ARLCB-TR-84017 ARLCB-TR-84022
Endochronic Theory of Plasticity	ARLCB-TR-84001
Endurion Phosphate	ARLCB-TR-84003
Equivalent Full Charge (EFC)	ARLCB-TR-84039
Erosion	ARLCB-TR-84022 ARLCB-TR-84041
Euler Equations	ARLCB-TR-84028 ARLCB-TR-84029
Euler-Lagrange Equations	ARLCB-TR-84036
Extrusion	ARLCB-TR-84026 ARLCB-TR-84038
Fatigue Life	ARLCB-TR-84023 ARLCB-TR-84039
Finite Element Analysis	ARLCB-TR-84008 ARLCB-TR-84036

SUBJECT	REPORT NUMBER
Fracture (Mechanics)	ARLCB-TR-84009 ARLCB-TR-84021 ARLCB-TR-84023 ARLCB-TR-84025 ARLCB-CR-84034 ARLCB-MR-84035
Fracture Toughness	ARLCB-TR-84026
Gas Dynamics	ARLCB-TR-84015 ARLCB-TR-84020
Generative Systems	ARLCB-TR-84027
Godunov Method	ARLCB-TR-84002
Grain Boundary Diffusion	ARLCB-TR-84017
Graphics	ARLCB-TR-84040
Gun Barrels	ARLCB-TR-84041
Gun Tubes	ARLCB-TR-84019 ARLCB-TR-84039
Guns	ARLCB-SP-84024
Hardening	ARLCB-MR-84006 ARLCB-TR-84019
Harten's Total Variation Diminishing (TVD) Scheme	ARLCB-TR-84028 ARLCB-TR-84029
Heat Treatment	ARLCB-MR-84006 ARLCB-TR-84007
Heywood's Equation	ARLCB-TR-84037
High Density Alloys	ARLCB-CR-84034
High Modulus Graphite/Epoxy	ARLCB-TR-84042
High Pressure	ARLCB-TR-84026
Hollow Tubes	ARLCB-TR-84007
Howitzers	ARLCB-TR-84039

	•
SUBJECT	REPORT NUMBER
Hydrogen Embrittlement	ARLCB-MR-84013
Hydrostatics	ARLCB-TR-84026 ARLCB-TR-84038
Improved Conventional Armament System (ICAS)	ARLCB-CR-84010 ARLCB-CR-84011 ARLCB-CR-84012
Impulse Noise	ARLCB-TR-84028
J-R Curves	ARLCB-TR-84009
Lead (Metal)	ARLCB-TR-84017
Liquid Copper	ARLCB-TR-84022
Liquid Gum Propellants	ARLCB-SP-84014
Liquid Metal Embrittlement	ARLCB-TR-84017
Lug and Groove Connections	ARLCB-TR-84037
Machining	ARLCB-TR-84027
Magnesium Alloys	ARLCB-TR-84031
Manganese	ARLCB-TR-84003
Mechanical Properties	ARLCB-MR-84006
Metalworking	ARLCB-TR-84027
Method of Characteristics	ARLCB-TR-84002
Microprocessors	ARLCB-CR-84010 ARLCB-CR-84011 ARLCB-CR-84012
Microstructure	ARLCB-MR-84006
Mobile Robots	ARLCB-TR-84033
Monopropellants	ARLCB-SP-84014

SUBJECT	REPORT NUMBER
Muzzle Brakes	ARLCB-TR-84002 ARLCB-TR-84004 ARLCB-TR-84015 ARLCB-TR-84020
Muzzle Flash	ARLCB-TR-84015
Nonsymmetric-Shaped Grooves	ARLCB-TR-84037
Numerical Methods	ARLCB-TR-84029
Obstacle Detection	ARLCB-TR-84033
120 mm Cannons	ARLCB-CR-84010 ARLCB-CR-84011 ARLCB-CR-84012
Partial Differential Equations	ARLCB-TR-84008 ARLCB-TR-84036
Path Selection	ARLCB-TR-84033
Perforated Muzzle Brakes	ARLCB-TR-84002 ARLCB-TR-84004 ARLCB-TR-84015 ARLCB-TR-84020
Phosphates	ARLCB-TR- 84003
Photoelasticity	ARLCB-TR-84037
Plastic Deformation	ARLCB-TR-84005
Plastic Properties	ARLCB-TR-84001
Plating	ARLCB-TR-84042
Plot 10	ARLCB-TR-84040
Pressure Ratio	ARLCB-TR-84020
Pressure Vessels	ARLCB-TR-84023
Process Planning	ARLCB-TR-84027
Propellant Combustor Performance Tester (PCPT)	ARLCB-SP-84014

SUBJECT	REPORT NUMBER
Quenching	ARLCB-MR-84006 ARLCB-TR-84007
Radial Deformation	ARLCB-TR-84016
Rarefaction	ARLCB-TR-84002
Recoil Mechanisms	ARLCB-TR-84032
Recoilless Guns	ARLCB-TR-84028
Reduction in Cohesion	ARLCB-TR-84017
Reports .	ARLCB-SP-84024
Residual Stress	ARLCB-TR-84018 ARLCB-TR-84019 ARLCB-TR-84023
Reverse Yielding	ARLCB-TR-84005 ARLCB-TR-84019
Rings	ARLCB-TR-84021
Rocket Launchers	ARLCB-TR-84028
Rods	ARLCB-TR-84016
Rotating Bands	ARLCB-TR-84022
Saturation	ARLCB-TR-84030 ARLCB-TR-84031
Second Variations	ARLCB-TR-84008 ARLCB-TR-84036
Secondary Waves	ARLCB-TR-84028
Shock Bottles	ARLCB-TR-84020
Shock Waves	ARLCB-TR-84002 ARLCB-TR-84004
Sliding Bearings	ARLCB-TR-84032
Slope Estimation	ARLCB-TR-84033

SUBJECT	REPORT NUMBER
Specimen Characterization	ARLCB- ΓR-84025
Steel	ARLCB-MR-84006 ARLCB-TR-84007 ARLCB-TR-84018 ARLCB-TR-84022
Steel 4340	ARLCB-TR-84017
Storage Tubes	ARLCB-TR-84040
Stress Concentration	ARLCB-TR-84037
Stress Corrosion	ARLCB-CR-84034
Stress Intensity	ARLCB-TR-84021 ARLCB-MR-84035
Stress Strain Relations	ARLCB-TR-84001 ARLCB-TR-84005
Stress Waves	ARLCB-TR-84036
Tank Guns	ARLCB-TR-84032
Technical Publications	ARLCB-SP-84024
TEKEDIT Computer Program	ARLCB-TR-84040
Tensile Strength	ARLCB-TR-84026
Tensile Stress	ARLCB-TR-84037
Test Methods	ARLCB-TR-84009 ARLCB-TR-84025
Thermal Stresses	ARLCB-TR-84007
Thick-Wall Cylinders	ARLCB-TR-84021
Titanium Alloys	ARLCB-TR-84038
Torsion	ARLCB-TR-84001
Torsion Bars	ARLCB-TR-84005
Toughness	ARLCB-TR-84009

SUBJECT	REPORT NUMBER
Transformation Stresses	ARLCB-TR-84007
Tungsten Alloys	ARLCB-TR-84026 ARLCB-CR-84034 ARLCB-TR-84038
Ultrasonics	ARLCB-TR-84018
Uranium Alloys	ARLCB-TR-84038
Variance Systems	ARLCB-TR-84027
Venting	ARLCB-TR-84020
Vibration	ARLCB-TR-84016
Wave Propagation	ARLCB-TR-84016
Wear Resistance	ARLCB-TR-84003
White Layers	ARLCB-TR-84041
Zinc Allovs	ARLCB-TR-84031

AD NUMBERS--1984

REPORT NUMBER	AD NUMBER
ARLCB-TR-84001	A139 413
ARLCB-TR-84002	B080 848L
ARLCB-TR-84003	A139 434
ARLCB-TR-84004	A139 766
ARLCB-TR-84005	A140 897
ARLCB-MR-84006	A140 632
ARLCB-TR-84007	B082 345L
ARLCB-TR-84008	A142 505
ARLCB-TR-84009	A142 507
ARLCB-CR-84010	B082 926L
ARLCB-CR-84011	B082 366L
ARLCB-CR-84012	B083 398L
ARLCB-MR-84013	A142 504
ARLCB-SP-84014	B083 397L
ARLCB-TR-84015	B083 742L
ARLCB-TR-84016	A142 674
ARLCB-TR-84017	A143 785
ARLCB-TR-84018	A143 566
ARLCB-TR-84019	A145 892
ARLCB-TR-84020	B086 050L
ARLCB-TR-84021	A145 893
ARLCB-TR-84022	A145 889
ARLCB-TR-84023	A145 978
ARLCB-SP-84024	A145 894

AD NUMBERS--1984 (CONT.)

REPORT NUMBER	AD NUMBER
ARLCB-TR-84025	A146 566
ARLCB-TR-84026	B085 874L
ARLCB-TR-84027	A145 628
ARLCB-TR-84028	A149 426
ARLCB-TR-84029	A148 141
ARLCB-TR-84030	A147 830
ARLCB-TR-84031	A147 369
ARLCB-TR-84032	A147 736
ARLCB-TR-84033	A148 787
ARLCB-CR-84034	A149 843
ARLCB-MR-84035	A148 786
ARLCB-TR-84036	A149 716
ARLCB-TR-84037	A149 425
ARLCB-TR-84038	B089 524L
ARLC6-TR-84039	B091 480L
ARLCB-TR-84040	A149 715
ARLCB-TR-84041	A151 424
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ARLCB-TR-84001		
4. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED
STRESS DISTRIBUTION IN A CYLINDRICAL BAR SUBJECTED TO CYCLIC TORSIONAL LOADING		Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(a)
P. C. T. Chen		
H. C. Wu (University of Iowa)		
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
US Army Armament Research & Development Center Benet Weapons Laboratory, DRSMC-LCB-TL		AMCMS No. 6111.02.H600.011
		PRON No. 1A325B541A1A
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US Army Armament Research & Development Center Large Caliber Weapon Systems Laboratory Dover, NJ 07801		January 1984
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16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

5.

Presented at First Army Conference on Applied Mathematics and Computing, George Washington University, Washington, D.C., 9-11 May 1983. Published in proceedings of the conference.

19. KEY WORDS (Continue on reverse side if necessary and identity by block number)

Torsion Endochronic Theory
Cyclic Loading Stress Distribution
Cylindrical Bar Plasticity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The modified version of the endochronic theory of plasticity is applied to the problem of a cylindrical bar subjected to cyclic fully-reversed torsional loading. The governing equations of integral form are derived for pure shear deformation. Analytical techniques are employed in the solution of these equations. A material with appreciable cyclic hardening behavior is studied. The shear stress-strain curve of such a material under a strain-controlled (CONT'D ON REVERSE)

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REPORT DOCUMENTATION F		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
ARLCB-TR-84002		
4. TITLE (and Substitle) A METHOD OF ANALYZING PERFORATED MUZZLE BRAKE PERFORMANCE		5. Type of Report & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. Author(s) CPT Robert E. Dillon, Jr. Henry T. Nagamatsu (RPI, Troy, NY)		6. CONTRACT OR GRANT NUMBER(*)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research & Developm Benet Weapons Laboratory, DRSMC-LCB- Watervliet, NY 12189		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 2080.15.6000.0 PRON No. 1A1221B81A1A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research & Development Center Large Caliber Weapon Systems Laboratory Dover, NJ 07801		12. REPORT DATE February 1984
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17. DISTRIBUTION STATEMENT (of the obstract entered in Block 20, If different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Perforated Muzzle Brake Blast Overpressures Shock Waves Godunov Method of Characteristics Rarefaction

29. ASSTRACT (Continue on reverse ship if responsely and identity by block number) Excessive blast overpressures are adversely affecting the safety and performance of artillery crews. A recent trend has been the production of higher blast overpressures necessitated by the need for greater range of these weapons. The need for reduced recoil characteristics of these weapons has led to the use of muzzle brakes to attenuate the recoil momentum. One adverse effect of using a muzzle brake is the shifting of the blast field rearward, (CONT'D ON REVERSE)

20. ABSTRACT (CONT'D)

thus elevating the blast overpressure in the crew area. One possible method of providing a braking force without the high blast overpressure is the perforated muzzle brake. The device is an extension of the gun tube with vent nozzles to discharge the propellant gas radially, hence recovering a finite amount of recoil momentum. The method of characteristics is used to predict the performance of perforated muzzle brakes. The muzzle brake is configured with constant diameter nozzles to vent the propellant gases perpendicular from the axis of fire. An axisymmetric inviscid Godunov finite difference scheme is used to model the external flow field produced by the perforated muzzle brake. Predictions of recoil efficiency of a perforated brake are presented. Comparisons of the flow fields generated by the bare muzzle, a double baffle brake, and a perforated brake are made for a 20 mm gun.

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ARLCB -TR-84003 .		·
4. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED
EVALUATION OF MANGANESE PHOSE	HATE COATINGS	Final
		6. PERFORMING ORG. REPORT NUMBER
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18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and	Identify by block number)	
Manganese Phosphate Endurion Phosphate Corrosion Resistance Wear Resistance		
The corrosion and wear resistance of two different manganese phosphate coatings with supplementary coatings of either oil or heat cured solid film lubricant (SFL) were compared. The basic, heavy manganese phosphate was compared to manganese phosphate converted or modified via the "Endurion" process. The corrosion resistance of the Endurion phosphate was significantly superior to the basic manganese phosphate. Endurion phosphate with a supplementary coating of oil did not fail after 600 hours in the 5% salt spray chamber whereas basic		

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20. Abstract (cont'd)

manganese phosphate with a supplementary coating of SFL failed after 206 hours (91 - 133 hours with supplementary coatings of oil). However, the wear resistance of Endurion phosphate with supplementary coatings was approximately identical to the basic manganese phosphate with supplementary coatings.

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM		
1. REPORT NUMBER ARLCB-TR-84004 2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER		
4. TITLE (and Substite) AN EXPERIMENTAL STUDY OF PERFORATED MUZZLE BRAKES	5. Type of REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER		
7. AUTHOR(*) CPT Robert E. Dillon, Jr. Henry T. Nagamatsu (RPI, Troy, NY)	8. CONTRACT OR GRANT NUMBER(*)		
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research & Development Center Benet Weapons Laboratory, DRSMC-LCB-TL Watervliet, NY 12189	10. PROGRAM ELEMENT. PROJECT. TASK AREA & WORK UNIT NUMBERS AMCMS No, 2080.15.6000.0 PRON No. 1A1221B81A1A		
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES To be presented at the 17th Fluid Dynamics, Plasma Dynamics & Laser Conference, Snowmass, CO, 25 - 27 June 1984, sponsored by the AIAA.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Perforated Muzzle Brake Muzzle Blast

Shock Wave

very and identify by block number) A firing test was conducted to examine the recoil efficiency and blast characteristics of perforated muzzle brakes fitted to a 20 mm cannon. Recoil impulse blast overpressures, muzzle velocity, sequential spark shadowgraphs, and photographs of the muzzle flash structure were obtained. Three different muzzle devices were used with one device equipped with pressure transducers to measure the static pressure in the brake. Experimental results are compared with the earlier predictions of Dillon and Nagamatsu.

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REPORT DOCUMENTATION	READ INSTRUCTIONS BEFORE COMPLETING FORM		
T. REPORT NUMBER ARLCB-TR-84005	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) A MATERIAL MODEL FOR REVERSE YIELDIN APPLICATION TO TORSION	5. Type of Report & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER		
7. AUTHOR(*) Peter C. T. Chen	6. CONTRACT OR GRANT NUMBER(*)		
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research & Developm Benet Weapons Laboratory, DRSMC-LCB- Watervliet, NY 12189	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H600.011 PRON No. 1A425M541A1A		
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18. SUPPLEMENTARY NOTES

Published in ED SAIBEL 80th Anniversary Volume edited by Prof. F. F. Ling and I. Tadjbachsh, RPI.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Reverse Yielding Bauschinger Effect Torsion Bar

Plastic Deformation

24. ASSTRACT (Continue on reverse side if reseasony and identify by block number)

A theoretical model for reverse yielding is proposed with an attempt to give a better representation for some material such as a high strength steel. The Bauschinger effect factor is treated as a function of overstrain. The strain-hardening effect is taken into account with different parameters used for forward and reversed loading processes. The application of this model to the torsion problem in a cylindrical bar is shown.

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ARLCB-MR-84006					
4. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED			
OBSERVATIONS ON THE AUS-QUENCHING OF	GUN STEEL				
AND RELATED PROPERTIES		Final			
		6. PERFORMING ORG. REPORT NUMBER			
7. AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(*)			
Charles J. Nolan					
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18. SUPPLEMENTARY NOTES					
19. KEY WORDS (Continue on reverse side if necessary and Gun Steel	i identify by block number)				
Hardenability					
Aus-Quenching					
Microstructure					
Mechanical Properties					
20. ABSTRACT (Continue on reverse able if reservery and	identify by block number)				
A reforged tube section was aus-quenched and tempered. Tensile and Charpy V-					
notch properties were determined at three locations in the forging, as well as					
the parent tube. No significant differences were observed in the strength,					
ductility, or toughness of the aus-quenched forging as compared to the					
conventionally heat-treated parent t					
tempered martensitic microstructure	was obtained in	all sections for both			
methods of heat treatment.					

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AMCMS Nos. 5025.13.84200.01 and 502E.11.29400

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ARLCB-TR-84007			
4. TITLE (and Subtitle)		S. TYPE OF REPORT & PERIOD COVERED	
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10BES DURING THE QUENCHING PROCESS		6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(e)	·	8. CONTRACT OR GRANT NUMBER(4)	
J. D. Vasilakis			
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10 DROGRAM FI FMENT PROJECT TASK	
		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
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18. SUPPLEMENTARY NOTES

D,

Presented at First Army Conference on Applied Mathematics and Computing, George Washington University, Washington, D.C., 9-11 May 1983. Published in proceedings of the conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Quenching Process
Thermal Stresses
Transformation Stresses
ADINA Finite Element Code

HOLLOW Tubes

26. ABSTRACT (Continue on reverse olds If necessary and identify by block number)

During the heat treatment of components, the transient thermal stresses can be very high. This is especially true if a severe quench is required such as the quenching of steel gun tubes for the development of a martensitic grain structure. In addition to the large transient thermal stresses, severe transformation stresses also exist due to the structural volume change involved. If these stresses are high enough, inelastic response of the material must be (CONT'D ON REVERSE)

33

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considered and residual stresses will exist in the structure when the process is complete. In this report, both thermal and transformation stresses are computed for various quenching procedures using a hollow tube for the geometric model. The relative severity of the thermal and transformation stresses and the conditions under which they occur are discussed. A general purpose finite element code, ADINA, is used for the computation.

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4. TITLE (and Subtitle)	MOTONAT POD	5. TYPE OF REPORT & PERIOD COVERED
ON THE EXTREMUM OF BILINEAR FUN HYPERBOLIC TYPE PARTIAL DIFFERE		Final
	1	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(e)		8. CONTRACT OR GRANT NUMBER(#)
C. N. Shen		
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18. SUPPLEMENTARY NOTES

Presented at the First Army Conference on Applied Mathematics & Computing George Washington University, Washington, DC, 9-11 May 1983.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Second Variations

Hyperbolic Type PDE

Finite Element Method

Beam Equation

Bilinear Functional

20. ABSTRACT (Continue on reverse side if reservery and identify by block number)

Transient solutions of the hyperbolic type partial differential equations are needed for solving many engineering problems such as computing stress waves for gun dynamics or determining shock behaviors of penetration mechanics.

Variational procedures using the bilinear formulations with adjoint variables can serve as the theoretical basis in the derivation of algorithms for the (CONT'D)

finite element methods, giving direct numerical solutions for partial derivatives of the functions to be found for these problems. The adjoint system can be arranged in a manner that it is a reflected mirror of the original system in time. Generalized boundary conditions employ many types of "springs" relating the various spatial partial derivatives. They are defined to satisfy the boundaries of the concomitant for the bilinear expression. Algorithms for use in the finite element method are simplified since the adjoint system gives exactly the same solutions as that of the original system. The second necessary condition for an extremum is satisfied by showing that the second variation is positive semi-definite.

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1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
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4. TITLE (and Subsiste) J-R CURVE DETERMINATION USING PRECRA	ACKED CHARPY	5. TYPE OF REPORT & PERIOD COVERED
SPECIMENS AND THE LOAD-DROP METHOD		Final
GROWTH MEASUREMENTS		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Joseph A. Kapp		8. CONTRACT OR GRANT NUMBER(*)
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18. SUPPLEMENTARY NOTES

Presented at Sixteenth National Symposium on Fracture Mechanics, Columbus, Ohio, 15-18 August 1983.
Published in proceedings of the symposium.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fracture

Test Methods

J-R Curves

Toughness

Precracked Charpy Specimens

20. ABSTRACT (Costinue on reverse stds if necessary and identify by block number)

J-R curves for two aluminum alloys, a titanium alloy and a high strength-low alloy steel at two different strength levels were determined using precracked Charpy specimens. Three methods were used to measure crack growth: (1) multispecimen, (2) compliance unloading, and (3) the "load-drop" method. The "load-drop" method assumes that crack growth occurs only after peak load has been attained and the amount which the load decreases after peak load is related to (CONT'D ON REVERSE)

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the size of the uncracked ligament. Comparisons between the three methods for all of the materials show remarkably similar J-R curves. Also, using these curves to determine a $J_{\rm IC}$ indicates very little difference between the "load-drop" method and the others in the measurement of toughness.

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4. TITLE (and Subtitle) IMPROVED CONVENTIONAL ARMAMENT SYSTEM AUTOLOADER		5. TYPE OF REPORT & PERIOD COVERED Final Sep 1983 - Feb 1984
		6. PERFORMING ORG. REPORT NUMBER
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9. PERFORMING ORGANIZATION NAME AND ADDRESS Emerson Electric Company Electronics and Space Division 8100 W. Florissant, St. Louis, Miss	ouri 63136	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
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18. SUPPLEMENTARY NOTES

Donald E. Jones - Benet Weapons Laboratory Project Engineer

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Autoloader LAP Basic Issue Module

120mm Cannon **AFARV** Separated Ammunition Brass 2000 **ICAS** Remote Operation Ammunition Canister Pneumatic Ramming

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A conceptual design for a 120mm Improved Conventional Armament System (ICAS) autoloader is presented in this report. This is a multiple mechanism system using microprocessor control. It is designed to load a separated round of ammunition at a rate of 8-12 rounds per minute. The ammunition is packaged in a single canister and transported in a Basic Issue Module. The autoloader is totally remote. Provisions have been made for manual loading under emergency situations. (CONT'D ON REVERSE)

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High reliability goals have been set and human factors engineering has been applied to this design. Program costs and a cost estimate to fabricate a laboratory demonstrator are included.

A data package consisting of Level 1 drawings presents the design in detail and is not included in this report.

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 2. GOVT ACCESSION NO Contractor Report ARLCB-CR-84011	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) CONCEPTUAL AUTOLOADER DESIGN STUDY FOR FUTURE ARMAMENT SYSTEM FOR COMBAT VEHICLES (FASCV)	5. TYPE OF REPORT & PERIOD COVERED Final Sep 1983 - Feb 1984 6. PERFORMING ORG. REPORT NUMBER E-2258
7. AUTHOR(*) B. D. Goodell R. A. Dahl M. W. Osborne R. V. Hettwer R. C. H. Schmidt	DAAA22-83-C-0197
9. PERFORMING ORGANIZATION NAME AND ADDRESS FMC Corporation Northern Ordnance Division 4800 East River Road, Minneapolis, MN 55421	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
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16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the obstract entered in Block 20, if different from Report)

IS. SUPPLEMENTARY NOTES

Donald E. Jones - Benet Weapons Laboratory Project Engineer

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Autoloader AFARV
120mm Cannon Brass 2000
Separated Ammunition Chain Rammer
ICAS Remote Operation

LAP Containerized Ammunition Package

20. ABSTRACT (Continue on reverse olds if reseasony and identify by block number)

A conceptual design for a 120mm Improved Conventional Armament System (ICAS) autoloader is presented in this report. This is a multiple mechanism system using microprocessor control. It is designed to load a separated round of ammunition at a rate of 8-12 rounds per minute. The ammunition is packaged in a single canister and transported in a five-round clip which is integral to the autoloader. The autoloader is totally remote. Provisions have been made for manual loading under emergency situations.

(CONT'D ON REVERSE)

High reliability goals have been set and human factors engineering has been applied to this design. Program costs and a cost estimate to fabricate a laboratory demonstrator are included.

A data package consisting of Level 1 drawings presents the design in detail and is not included in this report.

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
REPORT NUMBER 2. GOVT ACCESSION N	IO. 3. RECIPIENT'S CATALOG NUMBER
Contractor Report ARLCB-CR-84012	
. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
CONCEPTUAL DESIGN FOR 120mm IMPROVED	Final
CONVENTIONAL ARMAMENT SYSTEM (ICAS)	Sep 1983 - Feb 1984
AUTOLOADER	6. PERFORMING ORG. REPORT NUMBER
	FTR-ICAS-01
- AUTHOR(*)	8. CONTRACT OR GRANT NUMBER(*)
James E. Wildman	DAAA22-83-C-0198
. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK
ARES, Inc.	AREA & WORK UNIT NUMBERS
Bldg. 818, Front St., Erie Industrial Park	
Port Clinton, Ohio 43452	i i
1. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
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Large Caliber Weapon Systems Laboratory	13. NUMBER OF PAGES 352
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US Army Armament Research & Development Center	UNCLASSIFIED
Benet Weapons Laboratory, DRSMC-LCB-TL	- · · · -
Watervliet, NY 12189	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
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critical technology; April 1984. Other requests referred to Commander, US Army Armament Research	for this document must be and Development Center, atervliet, NY 12189.
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situations. The system has an integral auxiliary hydraulic power unit, for silent watch applications or there is vehicle system power failure.

High reliability goals have been set and human factors engineering has been applied to this design. Program costs and a cost estimate to fabricate a laboratory demonstrator are included.

A data package consisting of Level 1 drawings presents the design in detail and is not included in this report.

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. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
ARLCB-MR-84013			
. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED	
Cadmium Plating vs. Other Coati	ings to Prevent	Final	
		6. PERFORMING ORG. REPORT NUMBER	
AUTHOR(e)		8. CONTRACT OR GRANT NUMBER(s)	
R. A. FARRARA			
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U.S. Armament Research and Deve		AMCMS NO: 3111.16.2223	
Benet Weapons Laboratory, DRSMC-LCB-TL Watervliet, N.Y. 12189		D.A. Proj.	
		PRON_NO: 1A0204921A1A	
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

0

19. KEY WORDS (Continue on reverse side if necessary and identify by block number) .

Corrosion Protection Coatings Hydrogen Embrittlement

29. ASSTRACT (Continue on reverse side if necessary and identity by block number)

The electrodeposited cadmium coating used to prevent corrosion of screws can cause hydrogen embrittlement type failures. Protective coatings applied to screws by processes other than electrodeposition were tested for corrosion resistance (5% salt spray test). The corrosion resistance of cadmium plated screws was significantly superior to the other coarings selected as possible canidates for replacing cadmium.

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ARLCB-SP-84014	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED
The Propellant Combustor Performance Tester		Final
		6. PERFORMING ORG. REPORT NUMBER
- AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(#)
Alfred R. Graham		
PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
U. S. Armament Research and Development Center Benet Weapons Laboratory,DRSMC-LCB-TL Watervliet, N. Y. 12189		AMCMS No.6111.01.91A0.0
		PRON NO.1A325D021A1A
1. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Presented at the 1984 JANNAF Propulsion meeting, Marriot Hotel, New Orleans, LA, 7-8 Feb. 1984. To be published in the proceedings of the meeting

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Experimental Propellant Performance Regenerative Liquid Propellant Gun Fractional Burning Rate Combustion Liquid Monopropellant Characteristic Exhaust Velocity Completeness of Combustion

20. ABSTRACT (Continue on reverse ship if necessary and identify by block number)

A newly conceived test device, the Propellant Combustor Performance Tester, has the ability to measure the performance of various liquid monopropellants under steady state conditions at gun pressures; performance is measured in terms of the characteristic exhaust velocity c*. A rocket-like combustion chamber is used, and length may be varied so that flame length, or characteristic length L* may be measured; as well as the fractional burning rate, closely associated with accoustical combustion instability. For a given propellant, the effect of injector configuration may also be studied.

DD 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE 47

20. Abstract (cont'd)

This device has been designed and built with successful preliminary shakedown tests complete. The Propellant Combustor Performance Tester (PCTP), once developed, can be applied immediately to evaluate potential liquid propellants for LP gun application, from a combustion standpoint. It can be used directly to solve combustion instability problems in RLPGs.

The Propellant Combustor Performance Tester can become the new standard of the Regenerative Liquid Propellant Gun industry.

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1. REPORT NUMBER 2	. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
ARLCB-TR-84015		
N. TITLE (and Subtitle) A PARAMETRIC STUDY OF PERFORATED MUZI	ZLE BRAKES	5. TYPE OF REPORT & PERIOD COVERED
		Final
		6. PERFORMING ORG. REPORT NUMBER
7. Author(*) Robert E. Dillon, Jr.		8. CONTRACT OR GRANT NUMBER(*)
D. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research & Developme Benet Weapons Laboratory, DRSMC-LCB-1 Watervliet, NY 12189		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 2080.15.6000.0 PRON No. 1A1221B81A1A
1. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE
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14. MONITORING AGENCY NAME & ADDRESS(II different from Controlling Office)		15. SECURITY CLASS. (of this report)
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17. DISTRIBUTION STATEMENT (of the obstract entered in Block 20, if different from Report)

16. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side it necessary and identify by block number)
Perforated Muzzle Blast

Muzzle Blast Muzzle Flash Overall Efficiency Gas Dynamic Efficiency

20. ABSTRACT (Continue on reverse olds if responsery and identify by block number)

A firing test was conducted to study the parameters influencing the recoil efficiency and the blast characteristics of perforated muzzle brakes. Several scaled (20 mm) devices were tested as candidates for the 105 mm Light Assault Vehicle. Recoil impulse, blast overpressures, muzzle velocity, sequential spark shadowgraphs, and photographs of the muzzle flash were obtained. A total of nine different perforated brakes were tested as well as a scaled M198 double muzzle brake.

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1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
ARLCB-TR-84016		
4. TITLE (and Subtitle) LONGITUDINAL VIBRATIONS OF RODS OF I	ZINITE LENGTH	5. TYPE OF REPORT & PERIOD COVERED
WITH RADIAL DEFORMATION		Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(4)
Julian J. Wu and W. H. Chen (see rev	verse)	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	Contar	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
US Army Armament Research & Development Center Benet Weapons Laboratory, DRSMC-LCB-TL Watervliet, NY 12189		AMCMS No. 6111.02.H600.011
		PRON No. 1A325B541A1A
11. CONTROLLING OFFICE NAME AND ADDRESS	Contor	12. REPORT DATE
US Army Armament Research & Develop	tory	May 1984
Large Caliber Weapon Systems Laboratory		13. NUMBER OF PAGES
Dover, NJ 07801		25 15. SECURITY CLASS. (of this report)
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16. DISTRIBUTION STATEMENT (of this Report)

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18. SUPPLEMENTARY NOTES

Presented at Second International Modal Analysis Conference, Orlando, FL, 6-9 February 1984.
Published in proceedings of the conference.

19. KEY WORDS (Continue on reverse side if necessary and identity by block gumber)
Vibrations

Wave Propagation

Rods

Approximate Theory
Eigenvalue Problems

An approximate theory of dynamics of rods was formulated by Mindlin and Herrmann in 1951. The unique feature of this theory is that it can model the longitudinal as well as the radial motions of a rod, and yet it can retain the simplicity of a one-dimensional problem in the axial direction. Solutions pertaining to rods of infinite length were also given by Mindlin and Herrmann. This report presents vibration solutions of this rod model with finite lengths. First, (CONT'D ON REVERSE)

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7. AUTHORS (CONT'D)

W. H. Chen
Department of Power Mechanical Engineering
National Tsing Hua University
Hsinchu, Taiwan, Republic of China

20. ABSTRACT (CONT'D)

the set of two partial differential equations is recapitulated together with appropriate boundary conditions. For vibration problems, two sets of eigenvalue problems are formulated to satisfy the simultaneous partial differential equations and the homogeneous boundary conditions. Suitable parameters are defined to describe the dispersion relations. These dual eigenvalue matrix equations are then solved numerically. For an infinite rod, a dispersion relation of frequency versus wave number which contains an imaginary branch has been obtained. The free vibration problem of a fixed-fixed Mindlin-Herrmann rod has been solved. The numerical values of six (6) lowest frequencies, the associated wave numbers and mode shapes are tabulated for three different slenderness ratios.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-84017	. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EMBRITTLEMENT OF 4340 TYPE STEEL BY LIQUID LEAD AND ANTIMONY AND LEAD-ANTIMONY SOLUTIONS		5. TYPE OF REPORT & PERIOD COVERED FINAL 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(*) M. H. Kamdar		8. CONTRACT OR GRANT NUMBER(*)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research & Developme Benet Weapons Laboratory, DRSMC-LCB-7 Watervliet, NY 12189		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No.6111.02.H600.011 PRON NO.1A325B541A1A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research & Development Center Large Caliber Weapon Systems Laboratory Dover, NJ 07801		May 1984 13. NUMBER OF PAGES 24
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18. SUPPLEMENTARY NOTES

Presented at 1982 Meeting of AIME, St. Louis, MO, 24-28 October 1982 and published in the Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Liquid Metal Embrittlement Grain Boundary

Grain Boundary Diffusion

Mechanisms of Embrittlement

Reduction in Cohesion

Embrittlement of 4340 Type Steel

Embrittlement by Lead, Antimony, and

Lead-Antimony Solutions

20. ABSTRACT (Continue on reverse side if recovery and identify by block number)

A study has been made of the fracture behavior of single-edge notched specimens of 4340 type steel tested in cyclic fatigue at temperatures ranging from 675°F to 1350°F in high purity lead and antimony and liquid lead containing 5 to 75 percent antimony in solution. The susceptibility to embrittlement by liquid lead decreases with temperature. The fracture mode changes from intergranular at low temperatures to ductile at 1200°F. In lead solutions, at low (CONT'D ON REVERSE)

temperatures (700°F) and low concentrations of antimony (5 to 25 percent), embrittlement is caused by liquid lead only. At high temperatures (1000 to 1200°F) and high concentrations of antimony (35 to 75 percent Sb), antimony is the primary embrittling species. Antimony induced embrittlement by lead-antimony solutions occurs by intergranular fracture mode. This variation in susceptibility to embrittlement with temperature indicates that at low temperatures embrittlement is caused by liquid lead and occurs by "reduction in cohesion" mechanism; while at elevated temperatures embrittlement is induced by antimony and occurs by temperature dependent grain boundary diffusion controlled processes. These and other results are also discussed in terms of the current understanding of liquid metal and temper embrittlement of metals.

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1. REPORT NUMBER	. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
ARLCB-TR- 84018		
4. TITLE (and Subtitle) RESIDUAL STRESS MEASUREMENT IN CIRCU	TAD CTTT	5. TYPE OF REPORT & PERIOD COVERED
CYLINDER	LAK SICEL	Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(*) J. Frankel, W. Scholz*, G. Capsimalis, and W. Korman (*See reverse)		8. CONTRACT OR GRANT NUMBER(#)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research & Development Center Benet Weapons Laboratory, DRSMC-LCB-TL Watervliet, NY 12189		10. PROGRAM ELEMENT. PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6940. OR. 3570. O Prom No. 1A425N1A1A
11. CONTROLLING OFFICE NAME AND ADDRESS	ant Contain	12. REPORT DATE
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14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office)		15. SECURITY CLASS. (of this report)
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18. SUPPLEMENTARY NOTES

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Presented at the IEEE Symposium on Sonics & Ultrasonics, at Atlanta, GA, 31 Oct - 2 Nov 1983. To be published in the Symposium proceedings.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Ultrasonics

Residual Stress

my and identify by block man

Hoop residual stresses in a right circular steel cylinder were determined by ultrasonic velocity measurements. The zero stress position was obtained from an equilibrium condition, setting the integrated tensile equal to the integrated compressive hoop stress. Absolute stress values were obtained with the help of calibration measurements on a rectangular test bar of the same material, which was subjected to known applied forces. The stresses determined (CONT'D ON REVERSE)

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7. AUTHOR(S) (CONT'D)

*W. Scholz
Physics Department
State University of New York at Albany
Albany, NY 12222

20. ABSTRACT (CONT'D)

from these ultrasonic velocity measurements are in good agreement with values obtained by x-ray diffraction analysis of lattice strains.

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1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
ARLCB-TR-84019		
4. TITLE (and Subtitle) THE BAUSCHINGER AND HARDENING EFFECTS ON RESIDUAL STRESSES IN AN AUTOFRETTAGED THICK-WALLED CYLINDER		5. TYPE OF REPORT & PERIOD COVERED
		Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Peter C. T. Chen		8. CONTRACT OR GRANT NUMBER(*)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research & Development Center Benet Weapons Laboratory, DRSMC-LCB-TL Watervliet, NY 12189		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H600.011 PRON No. 1A425M541A1A
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		June 1984 13. NUMBER OF PAGES 17
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16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at 1984 Pressure Vessel and Piping Conference, San Antonio, Texas, 17-21 June 1984.

Published in ASME Journal of Pressure Vessel Technology.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Residual Stress Bauschinger Effect

Autofrettage

Hardening Effect

Gun Tube

D,

Reverse Yielding

20. ABSTRACT (Continue on reverse etc # necessary and identify by block number)
Most of the earlier solutions for residual stresses were based on the assumption of elastic unloading and only a few considered reverse yielding. In this report a new theoretical model for a high strength steel is proposed and a closed-form solution for calculating residual stresses in autofrettaged tubes has been obtained. The new results indicate that the influence of the combined Bauschinger and hardening effects on the residual stress distribution is significant.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-84020	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
ARLCB-TR-84020 4. TITLE (and Subtitle) WALL THICKNESS AND VENT AREA EFFECTS ON PERFORATED MUZZLE BRAKE PERFORMANCE		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(*) CPT Robert E. Dillon, Jr.		8. CONTRACT OR GRANT NUMBER(a)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research & Development Center Benet Weapons Laboratory, DRSMC-LCB-TL Watervliet, NY 12189		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 2080.15.6000.0 PRON No. 1A1221B81A1A
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16. DISTRIBUTION STATEMENT (of this Report)

Distribution limited to US Government Agencies and their contractors because of critical technology; June 1984. Other requests for this document must be referred to Commander, US Army Armament Research and Development Center, ATTN: Benet Weapons Laboratory, DRSMC-LCB-RA, Watervliet, NY 12189.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, If different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identity by block number)
Shock Bottle
Pressure Ratio
Ballistic Efficiency
Gas Dynamic Efficiency

29. ASSTRACT (Cantinue on reverse som if resectory and identify by block number)

The firing data of fourteen different perforated muzzle brakes are analyzed in order to describe the parameters of importance to perforated muzzle brake performance. Numerical simulations were made for 20 mm and 105 mm muzzle conditions to study the flow structure in the vent nozzles. Optimum wall thicknesses were identified for various muzzle brake configurations. Blast overpressure levels and recoil efficiencies of all the devices tested are presented.

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1. REPORT NUMBER 2. GOVT ACCES	SION NO. 3. RECIPIENT'S CATALOG NUMBER
APLCB-TR-84021	
4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
STRESS INTENSITY FACTORS FOR A CIRCULAR RING WITH UNIFORM ARRAY OF RADIAL CRACKS OF UNEQUAL	Final
DEPTH	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(e)	8. CONTRACT OR GRANT NUMBER(#)
S. L. Pu	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
US Army Armament Research & Development Center	
Benet Weapons Laboratory, DRSMC-LCB-TL	PRON NO. 1A325B541A1A
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17. DISTRIBUTION STATEMENT (of the obstract entered in Block 20, If different from Report)

18. SUPPLEMENTARY NOTES

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Presented at Second Conference on Applied Mathematics & Computing, RPI, Troy, NY, 22-24 May 1984. To be published in the Proceedings of same conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Stress Intensity Factors

Multiple Cracks

Cracks of Unequal Lengths

Fracture Mechanics

Thick-Wall Cylinders

20. ABSTRACT (Continue on reverse olds if necessary and identify by block number)

The plane problem of a uniform array of unequal depth radial cracks originating at the internal boundary of a pressurized circular ring is considered. The 12node quadrilateral isoparametric elements with collapsed singular elements around crack tips are used to compute stress intensity factors at crack tips.

(CONT'D ON REVERSE)

TO SECURE OF THE PROPERTY OF T

In a previous study of equal depth radial cracks, the weakest configuration is a ring with two diametrically opposed cracks. The current study shows that if for any reason one of the two cracks should grow a little faster than the other, the stress intensity factor at the tip of the longer crack increases at a much faster rate to enhance the faster growth of the longer crack.

Numerical results are also obtained for cases of three and four radial cracks. It shows the same trend that once one or two cracks grow a little more than the rest, the stress intensity factors at these deeper cracks will be increased progressively higher to keep the faster pace of growth. This explains why the failure caused by a single major crack has been observed most frequently.

A simple linear relation is assumed in this report between the stress intensity ratio and the crack depth ratio. This approximation enables us to estimate stress intensity factors at unequal depth cracks by a method of total differentials. The estimations thus obtained are close to stress intensity factors computed from the finite element.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER ARLCB-TR-84022	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitio)		5. TYPE OF REPORT & PERIOD COVERED	
EMBRITTLEMENT OF GUN STEEL BY COPPER		Final	
		6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(e)		8. CONTRACT OR GRANT NUMBER(4)	
R. M. Fisher, A. Szirmae, and (CONT'D ON REVERSE)	M. H. Kamdar		
9. PERFORMING ORGANIZATION NAME AND	ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
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17. DISTRIBUTION STATEMENT (of the obstract entered in Stock 20, if different from Report)

Presented at Fall Symposium of AIME, 24-28 October 1982, St. Louis, MO. Published in the Proceedings of Symposium on Liquid and Solid Metal Induced Embrittlement.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Embrittlement

Liquid Copper

Gun Steel

Cracking by Copper

Copper Rotating Band

Rotating Bands

Erosion

20. ABSTRACT (Continue on reverse side if negocoary and identify by block number)

Metallographic examination of the bore surfaces of cannon tubes revealed a close association of copper with the erosion and cracking that occurs during firing. Metallic copper, transferred by abrasive contact between the steel surface and the copper rotating band on the projectile that engages the rifling, can induce embrittlement and enhance propagation of cracks developed by the thermal-mechanical stresses generated during firing. Corroborative experiments (CONT'D ON REVERSE)

EDITION OF 1 NOV 45 IS OBSOLETE 63 DD 1 JAN 73 1473

Unclassified

7. AUTHORS (CONT'D)

R. M. Fisher and A. Szirmae U.S. Steel Corporation Research Laboratory Monroeville, PA 15146

20. ABSTRACT (CONT'D)

using capacitance discharge heating verified that copper-induced embrittlement and cracking can occur during a thermal pulse of only a few milliseconds duration. Hot tensile testing with a Gleeble machine confirmed that copper penetrates austenite grain boundaries causing hot tearing in just a few seconds at 1000°C, i.e., well below the melting point of copper.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
I. REPORT NUMBER 2.	. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
ARLCB-TR-84023		
A. TITLE (and Subtitle) A SIMPLE, FRACTURE MECHANICS BASED METHOD FOR		5. TYPE OF REPORT & PERIOD COVERED
FATIGUE LIFE PREDICTION IN THICK-WALLED		Final
CYLINDERS		6. PERFORMING ORG. REPORT NUMBER
7. Author(*) David P. Kendall		8. CONTRACT OR GRANT NUMBER(#)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research & Developme Benet Weapons Laboratory, DRSMC-LCB-T		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
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17. DISTRIBUTION STATEMENT (of the obstract entered in	Block 20, It different from	n Report)
18. SUPPLEMENTARY NOTES		-
Presented at ASME Pressure Vessel 18-21 June 1984.	& Piping Confer	ence, San Antonio, Texas,
19. KEY WORDS (Continue on reverse side if necessary and Pressure Vessels Fatigue Fracture Mechanics Bauschinger Effect Residual Stress	identify by block number)	
Amethod is proposed for predicting to based on numerical integration of the from a fracture mechanics analysis. stresses, crack shape, and of the confactor are accounted for. A method stresses for the Bauschinger Effect,	the fatigue life e fatigue crack The effects of mpressive portion for correcting t	growth curve as determined autofrettage residual on of the stress intensity the autofrettage residual

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Peter Chen, is also included. A simple computer program for performing the calculation of fatigue life is presented along with a comparison of the calculated results with the experimental results of Davidson, and of Throop and Fujczak.

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1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
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4. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED	
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TECHNICAL REPORTS - 1983		6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(#)	
R. D. Neifeld			
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
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Benet Weapons Laboratory, DRSMC-LC Watervliet, NY 12189	D-1L		
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE	
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Abstracts			
Document Control Data			
20. ABSTRACT (Continue on reverse side H necessary and identify by block number)			
This is a compilation of Benet Weapons Laboratory technical reports			
published during 1983.			
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. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED
WIDE RANGE DISPLACEMENT EXPRESSIONS FOR STANDARD FRACTURE MECHANICS SPECIMENS		Fi-al
		Final
		6. PERFORMING ORG. REPORT NUMBER
· AUTHOR(e)		8. CONTRACT OR GRANT NUMBER(*)
J. A. Kapp, G. S. Leger, and Bern (CONT'D ON REVERSE)	ard Gross	
PERFORMING ORGANIZATION NAME AND ADDRE	ESS	10. PROGRAM ELEMENT, PROJECT, TASK
JS Army Armament Research & Develo	opment Center	AMCMS No. 6111.02.H600.011
Benet Weapons Laboratory, DRSMC-LCB-TL Watervliet, NY 12189		PRON No. 1A325B541A1A
1. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE
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16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at Sixteenth National Symposium on Fracture Mechanics, Columbus, Ohio, 15-18 August 1983.
Published in proceedings of the symposium.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Practure Mechanics Testing Methods Specimen Characterization

20. ABSTRACT (Courtieus on reverse stds if necessary and identity by block number)

Wide range algebraic expressions for the displacement of cracked fracture mechanics specimens are developed. For each specimen two equations are given: one for the displacement as a function of crack length and the other for crack length as a function of displacement. All of the specimens that appear in ASTM Standard E-399 are represented in addition to the crack mouth displacement for a pure bending specimen. For the compact tension sample and the disk-shaped (CONT'D ON REVERSE)

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7. AUTHORS (CONT'D)

G. S. Leger Graduate Student Mechanical Department University of New Mexico Albuquerque, NM 87106

Bernard Gross Materials Engineer NASA-Lewis Research Center Cleveland, OH 44135

20. ABSTRACT (CONT'D)

compact tension sample, the displacement at the crack mouth and at the load line are both considered. Only the crack mouth displacements for the arc-shaped tension samples are presented. The agreement between the displacements or crack lengths predicted by the various equations and the corresponding numerical data from which they were developed are nominally about three percent or better. These expressions should be useful in all types of fracture testing including $J_{\rm IC}$, $K_{\rm R}$, and fatigue crack growth.

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I. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
ARLCB-TR-84026		,	
4. TITLE (and Subtitle) HYDROSTATIC EXTRUSION AND MECHANICAL PROPERTIES OF TUNGSTEN ALLOY PENETRATORS		5. TYPE OF REPORT & PERIOD COVERED FINAL	
		6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(*) Charles J. Nolan and M. H. Kamdar		8. CONTRACT OR GRANT NUMBER(*)	
9. Performing organization name and address US Army Armament Research & Development Center Benet Weapons Laboratory, DRSMC-LCB-TL Watervliet, NY 12189		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No.6446.01.0310.0 PRON No.1A425V641A1A	
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research & Development Center Large Caliber Weapon Systems Laboratory Dover, NJ 07801		12. REPORT DATE August 1984	
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19. KEY WORDS (Continue on reverse side if necessary as Warm Hydrostatic Extrusion	nd identify by block number)	nsile Strength	
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Liquid Phase Sintered Tungsten Alloy Fracture Toughness High Pressure Fracture Mode

20. ABSTRACT (Complement reverse with N recessary and Identify by block number)
An investigation was conducted to determine the effect of large deformations on the mechanical properties and fracture mode of liquid phase sintered 90W-7Ni-3Fe alloy. The alloy was hydrostatically extruded to 20, 50, and 65 percent reduction-in-area at 500°F. The strengthening of the alloy occurred by plastic deformation of both the matrix phase and the tungsten grains. The yield and the ultimate tensile strengths in excess of 200 Ksi were obtained by warm extruding (CONT'D ON REVERSE)

50 and 65 percent with adequate ductility and fracture toughness. A transition in the fracture mode from interparticle separation to transcrystalline cleavage was observed for the extruded material. The ballistic performance of the extruded alloy was significantly superior to that of swaged material and this appears to be related to the change in the fracture mode.

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ARLCB-TR-84027			
4. TITLE (and Subtitio)	<u></u>	5. TYPE OF REPORT & PERIOD COVERED	
Computer Aided Process Planning of Machined		Final	
Metal Parts			
		6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(*)	
Captain Walter W. Olson	_		
9. PERFORMING ORGANIZATION NAME AND ADDRESS Armament Research & Dev Center, HQ	II C Arms	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
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Weapons Laboratory, Watervliet, NY		DA ProjectM1-1-P2613-M1-1A	
11. CONTROLLING OFFICE NAME AND ADDRESS		PRON No. 68V7724	
Armament Research & Dev Center, HQ,	IIC Assert		
Armament, Munitions and Chemical Co		September 1984	
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18. SUPPLEMENTARY NOTES	•		
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19. KEY WORDS (Continue on reverse side if necessary and			
Computer Aided Process Planning Machineability			
Variance Systems			
Generative Systems Functional Analysis			
Expert Systems			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)			
Although process planning is more of		science today, its auto-	
mation is both possible and feasible. Variant computer aided systems exist			
and can be applied now. These syst	ems should not h	ave a great effect upon	
Organizational structure Communication			

mation is both possible and feasible. Variant computer aided systems exist and can be applied now. These systems should not have a great effect upon organizational structure. Generalized generative process planning does not exist and probably will not in the near future. However, several special purpose generative systems are available in experimental form. The capabilities of these systems must be planned during the design by a judicious choice of approaches and properties to solve the process planning problem.

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		6. PERFORMING ORG. REPORT NUMBER
AUTHOR(*) Garry C. Carofano		8. CONTRACT OR GRANT NUMBER(*)
PERFORMING ORGANIZATION NAME AND US Army Armament Research & D Benet Weapons Laboratory, SMC Watervliet, NY 12189	Development Center	10. PROGRAM ELEMENT. PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H600.011 PRON No. 1A425M541A1A
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17. DISTRIBUTION STATEMENT (of the obstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Presented at the Technical Coordinating Panel Workshop on Weapon Launch Blast Overpressure, RARDE, Ft. Halstead, Kent, England, 26-29 July 1983. Published in proceedings of the workshop.

19. KEY WORDS (Continue on reverse side if necessary and identity by block number)
Impulse Noise Recoilless Rifles

Recoilless Rifles

Blast

Blast Computation

Rocket Launcher

Secondary Waves

20. ABSTRACT (Continue on reverse olds if necessary and identify by block number) Blast signatures at the gunner's position produced by recoilless rifles and rocket launchers often .xhibit a strong secondary wave following chamber blowdown. To id maify its source, a series of experiments was performed using a helium-driven blast simulator. The resulting pressure traces and shadowgraphs show the wave emerging from the portion of the plume just aft of the nozzle, but leave unexplained its relationship to the plume flow field structure. This inf rmation was obtained from a numerical solution of the Euler equations using (CONT'D ON REVERSE)

75

Harten's Total Variation Diminishing (TVD) scheme. Based on this data, contour and surface plots of pressure were constructed which reveal quite clearly the plume wave structure and its response to the falling chamber pressure. A secondary wave emerges from the same region of the plume as it did in the experiment.

REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
. REPORT NUMBER 2. GOVT ACCESSION NO.	
ARLCB-TR-84029	
. TITLE (and Substite) BLAST COMPUTATION USING HARTEN'S TOTAL VARIATION	5. TYPE OF REPORT & PERIOD COVERED
DIMINISHING SCHEME	Final
	6. PERFORMING ORG. REPORT NUMBER
Garry C. Carofano	8. CONTRACT OR GRANT NUMBER(+)
. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
US Army Armament Research & Development Center	AMCMS No. 6111.02.H600.011
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6. DISTRIBUTION STATEMENT (of this Report)	<u> </u>
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Blast Computation Numerical Methods

20. ABSTRACT (Centileus on reverse side if necessary and identify by block number)

A model for blast flow field calculations involving two distinct gases is described. It is based upon the Euler equations and Harten's Total Variation Diminishing (TVD) scheme is used as the equation solver. The eigenvalues and eigenvectors are first derived for a general equation of state. Then a particular equation of state is presented for a mixture of two ideal gases. The model predictions show good agreement with experimental data for a shock diffraction around a corner.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-84030	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ELECTRICAL RESISTIVITY IN LOW RESISTIVITY AMORPHOUS ALLOYS		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(*) L. V. Meisel and P. J. Cote		8. CONTRACT OR GRANT NUMBER(*)
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
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18. SUPPLEMENTARY NOTES

Presented at the Fifth International Conference on Liquid & Amorphous Metals, Los Angeles, California, 15-19 August 1983

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Amorphous Alloys Electron Transport Diffraction Model Saturation

20. ABSTRACT (Continue on reverse side M necessary and identify by block number)

The temperature dependence of the electrical resistivity in low resistivity ($\rho < 100~\mu\Omega cm)$ amorphous alloys is analyzed in the framework of the diffraction model. The standard diffraction model yields results in qualitative agreement with the available data. However, a quantitative agreement with the data is observed if phonon ineffectiveness effects are included by means of the Pippard-Ziman constraint. A variety of results are presented for ranges of $2k_{\rm F}/k_{\rm p}$ and electron mean free paths.

SECURITY CLASSIFICATION OF THIS PAGE (When Date Entered)

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ARLCB-TR-84031		
4. TITLE (and Subtitle)		S. TYPE OF REPORT & PERIOD COVERED
APPLICATION OF THE DIFFRACTION MODE	L TO AMORPHOUS	
MAGNESIUM ZINC ALLOYS		Final
MASKIDION BING MILESTO		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(#)
P. J. Cote and L. V. Meisel		
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18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary an	d identify by block number)	
Amorphous Alloys	•	
Electron Transport		1
Diffraction Model		
Saturation		
20. ABSTRACT (Continue on reverse stde if recessory on	Lidentify by block number)	
-		he best system available for
Amorphous magnesium-zinc (a-MgZn) alloys comprise the best system available for testing the diffraction model for electron transport in non-crystalline alloys.		
They are simple metal binary alloys. Conventional methods exist for determining		
electronic parameters in the model. They exhibit low resistivities so that		
saturation effects are not expected		
and extensive resistivity data are		
, 		(CONT'D ON REFERSE)

Computed results presented here are based on a refinement of previous calculations; the alloy scattering matrix elements with computed phase shifts for Mg and Zn are used with the substitutional model instead of the adjusted effective potential assumed previously. Results obtained ignoring mean free path effects are in qualitative agreement with the data; agreement is surprisingly detailed when account is taken of saturation effects.

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ARLCB-TR-84032		
4. TITLE (and Subtitle)		S. TYPE OF REPORT & PERIOD COVERED
EFFECT OF INTERCONNECTION OF THE EN SLIDING BEARING ON FILM THICKNESS	DS OF A	Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(a)		8. CONTRACT OR GRANT NUMBER(*)
R. S. Montgomery		
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18. SUPPLEMENTARY NOTES

To be presented at the 1984 ASME-ASLE LUBRICATION CONFERENCE, San Diego, CA October 22-24 1984

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Recoil Mechanisms Sliding Bearings Tank Guns

29. ABSTRACT (Continue on reverse olds if reseconcy and identify by block number)

The effect of the area of interconnection between the ends of fast-acting bearings such as those of recoil mechanisms used with American tank guns was studied with an apparatus which simulated a concentric recoil system. It was found that these bearings do not "starve" with a small interconnection area, but a larger area would probably produce a faster-acting bearing. It would also result in a thinner fluid film but this would probably be unimportant.

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The film thickness continues to increase for a time even after the movement of the recoiling tube has stopped, so there appears little chance that the film would entirely collapse before counter-recoil begins. There are two area ratios that result in thinner film thicknesses and slower formation of the fluid film. These area ratios should be avoided. Their locations were at 1.5 and 4.9 mm²/cm but they might be at different locations with the larger actual recoil bearings and with the geometries of specific designs.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER ARLCB-TR-84033	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
AUTONOMOUS NAVIGATION FOR MOBILE OVER HILLY TERRAIN USING RANGEFI MEASUREMENTS		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER	
7. Author(s) C. N. Shen		8. CONTRACT OR GRANT NUMBER(*)	
9. PERFORMING ORGANIZATION NAME AND ADDITUS Army Armament Research & Deve Benet Weapons Laboratory, SMCAR- Watervliet, NY 12189	lopment Center	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS NO. 6111.02.H600.011 PRON NO. 1A325B541A1A	
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Conference, Wayne State Univer		igence & Productivity igan, 18-19 Nov. 1983.	
19. KEY WORDS (Continue on reverse elde if necesse Mobile Robot Vehicle Navigation Obstacle Detection Slope Estimation	ry and identify by block number		

ey and identify by block number)

The mobile robot vehicle is equipped with data acquisition and decision making devices for its autonomous navigation over rough terrain. A laser rangefinder is chosen as principal sensing device, which can determine radial distances from the vehicle to points on unpredictable hilly terrain surfaces. The overall procedure conducted for such a design consists of the following interrelated subsystems such as scanning scheme, obstacle detection scheme, terrain slope estimation, and path selection algorithm. Stochastic processes and methods are employed throughout the analysis.

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Path Selection

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1. REPORT NUMBER 2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
Contractor Report ARLCB-CR-84034	
4. TITLE (and Subtitle) STRESS CORROSION CRACKING BEHAVIOR OF TUNGSTEN	5. TYPE OF REPORT & PERIOD COVERED
HEAVY ALLOYS	Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHÓR(e)	B. CONTRACT OR GRANT NUMBER(a)
Jin-Gon Chung	
David J. Duquette	DAAA22-81-C-0138
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18. SUPPLEMENTARY NOTES

Dr. Joseph A. Kapp - Benet Weapons Laboratory, Project Engineer

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

High Density Alloys

Stress Corrosion Cracking

Fracture

Fracture Mechanics

Fracture Mechanisms

20. ABSTRACT (Cantiline on reverse som if respecting and identity by block number)

Stress corrosion cracking behavior of 90W-Ni-Fe (W-10) and 97W-Ni-Fe+Cu-Co (W-3) alloys has been studied in solutions of NaCl, NACE, and 10% $\rm H_2SO_4$. The influences of electrochemical polarization, hydrogen catalyst, and heat treatment on KISCC, static load crack growth rate, and fracture morphology were studied.

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The W-10 alloy exhibited SCC susceptibility in NaCl solution. Electrochemical polarization, addition of a hydrogen catalyst (As) to the NaCl solution and heat treatment in hydrogen increased SCC susceptibility. SCC susceptibility was also observed in the sulfide cracking solution and when cathodically charged in 10% H2SO4 with a hydrogen catalyst (As). At the corrosion potential and anodic potentials in NaCl solution, SCC propagated by separation of tungsten-tungsten and tungsten-matrix interfaces with ductile rupture of the matrix. In other cases, cracks propagated by separation of tungsten-matrix and tungsten-tungsten interfaces with some cleavage of tungsten grains.

The W-3 alloy did not exhibit SCC susceptibility in NaCl solution, under any conditions. SCC did occur in the sulfide cracking solution and when cathodically charged in 10% H₂SO₄ with a hydrogen catalyst (As), however, it was much more resistant than the W-10 alloy. Fracture occurred primarily by dimple formation in the matrix and cleavage of tungsten grains.

SCC in the W-10 alloy is thought to occur by electrochemical dissolution of the matrix. Small matrix volume and high tungsten contiguity in the W-3 alloy prevents cracks from growing even though severe matrix dissolution occurs.

The observed susceptibility of both alloys to cracking in the NACE recommended sulfide cracking solution and when cathodically charged in 10% H₂SO₄ with As indicates that both alloys are highly susceptible to hydrogen embrittlement.

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		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(a)	-	8. CONTRACT OR GRANT NUMBER(*)
Fahmy M. Haggag (EG&G Idaho, Inc., Idaho Falls, ID) and J. H. Underwood		
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18. SUPPLEMENTARY NOTES

Submitted for publication in International Journal of Fracture.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Bend Specimen Compliance Stress Intensity Fracture Mechanics

20. ABSTRACT (Continue on reverse olds if necessary and identify by block number)

Load-line displacement information for the three-point bend specimen is presented and compared with information from the literature, with emphasis on the needs of those performing fracture tests.

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1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
ARLCB-TR-84036		
4. TITLE (and Substite) SECOND VARIATIONS FOR THE STRESS WAVE PROBLEM USING THE EULER-LAGRANGE AND ADJOINT FORMULATIONS		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) C. N. Shen		8. CONTRACT OR GRANT NUMBER(*)
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18. SUPPLEMENTARY NOTES

Submitted to Journal of Sound and Vibration.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Second Variations Adjoint Systems Hyperbolic P.D.E. Finite Element Bilinear Expression

The adjoint system can be arranged in a manner so it is a reflected mirror of the original system in time. Generalized boundary conditions employ many types of "springs" relating the various spatial partial derivatives. They are defined to satisfy the boundaries of the original and adjoint system relationship for the bilinear expression. Algorithms for use in the finite element method are simplified since the adjoint system gives exactly the same solutions (CONT'D ON REVERSE)

as those of the original system. The second necessary condition for an extremum is satisfied by showing that the second variation of the functional is positive semi-definite.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
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ARLCB-TR-84037		
I. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED
STRESS CONCENTRATION DUE TO AX	CIAL TENSION OF	
LOADED NONSYMMETRIC-SHAPED GRO	OOVES	Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(e)		B. CONTRACT OR GRANT NUMBER(#)
Y. F. Cheng		
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Presented at Fifth International Congress on Experimental Mechanics, Montreal, Canada, 10-15 June 1984. Published in proceedings of the congress.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Lug and Groove Connection Stress Concentration Nonsymmetric-Shaped Grooves Two-Dimensional Photoelasticity Heywood's Equation

20. ABSTRACT (Continue on reverse olds if necessary and identify by block number)

Lug and groove connections are frequently found in structures where two components meet and loads are transmitted. These grooves usually have a non-symmetric shape, i.e., the flank angle at the loaded face is different from that at the free face. While numerous data on stress concentrations for symmetric-shaped grooves (for example, U- or V-shaped) are available, very little information exists for nonsymmetric-shaped grooves. This report (CONT'D ON REVERSE)

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describes a photoelastic study on stress concentration in plates due to axial tension of loaded nonsymmetric-shaped grooves. Groove geometries as well as loading conditions are given. Maximum groove stresses were found and stress concentration factors were calculated. Also, parametric curves of stress concentration were obtained. A comparison was made between experimental results and those calculated by means of Heywood's equation.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
ARLCB-TR-84038		
4. TITLE (and Subtitle) STUDIES OF HYDROSTATIC COEXTRUSION	OF DEPLETED	S. TYPE OF REPORT & PERIOD COVERED
URANIUM-0.75 TITANIUM ALLOY REINFOR	CED WITH	Progress Report
TUNGSTEN FILAMENT (A PROGRESS REPORT)		6. PERFORMING ORG., REPORTINUMBER
7. AUTHOR(*) I. Ahmad, R. J. Fiorentino, E. G. Smith, Jr., and J. Barranco (see reverse)		8. CONTRACT OR GRANT NUMBER(*)
9. PERFORMING ORGANIZATION NAME AND ADDRESS	mont Center	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
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19. KEY WORDS (Continue on reverse side if necessary and identity by block number)
Uranium Interface

Tungsten Composites Ballistic Tests DU-0.75 Ti

Hydrostatic Extrusion

20. ABSTRACT (Cauthus an reverse state if necessary and identity by block number)

Composites of depleted uranium-0.75 titanium matrix alloy reinforced with nominally 0.5 V_f tungsten filaments have been fabricated by hydrostatic coextrusion. In the first stage, extrusion reduction ratio of 6:1 at 500-600°C was easily achieved. However, for further reduction, the ratio and temperature of extrusion of 4:1 and 400°C, respectively, were found to be optimum. At higher temperatures and reduction ratios, periodic necking and fracture of filaments occurred. To achieve the final reduction ratio of 48:1, the 24:1 (CONT'D ON REVERSE)

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7. AUTHOR(S) (CONT'D)

R. J. Fiorentino and E. G. Smith, Jr. Battelle Memorial Institute Columbus, OH

20. ABSTRACT (CONT'D)

stock obtained in the two-stage extrusion was successfully swaged at 400°C using multipasses. Attempts to eliminate the second extrusion step by following the first-stage extrusion at a 6:1 reduction with a final reduction by hot swaging at 400°C, were partially successful. The tungsten phase was uniformly reduced to 0.050 inch diameter filaments. However, the crosssection of the outer filament did not remain circular at 43:1 reduction rates. Also, cracks developed at the filament-matrix interface and within the filament. Mechanical tests showed that the composite had elastic modulus approaching rule of mixture values. However, the tensile and flexure strengths were lower than the matrix alloy. The matrix alloy specimen produced by two-stage hydrostatic extrusion of cast alloy had tensile properties as good as the conventonal heat treated alloy. In ballistic tests against medium heavy triple-spaced target, the matrix hydrostatically extruded alloy performed as well as the conventional alloy. Also, the composite specimens in spite of the longitudinal cracks, showed complete penetration at 1252 meters/sec striking velocity.

Preliminary ballistics tests showed that hydrostatically extruded (2:1) W-10 alloy outperformed swaged W-10 alloy.

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1. REPORT NUMBER 2	. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
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4. TITLE (and Subtitle) FATIGUE EFFECTS OF M4A2 ZONE 7 ROUND ON 155 MM M185 HOWITZER TUBE LIFE		5. TYPE OF REPORT & PERIOD COVERED	
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		6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(a) Bruce B. Brown		B. CONTRACT OR GRANT NUMBER(a)	
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Fatigue

Cannon

Howitzer

Gun Tube

EFC

o.

29. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The fatigue life of the 155 mm M185 howitzer tube has previously been established for the maximum pressure round, the M19Al Zone 8. This test program addresses the effects of the next lower pressure standard round - the M4A2 Zone 7. The objective of the program is to determine a recommended Equivalent Full Charge (EFC) factor to be used in accounting for fatigue cyclic increments counted towards the safe service life limit when using a less than full pressure round.

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This tube suffers fatigue failure from exterior initiating cracks caused by combined tensile residual stress and the tensile stress of firing pressure. Since the pressure difference of the two rounds is slight and is added to the constant residual stress, the percentage change is small and results in a negligible change in fatigue effect. The EFC factor for the M4A2 Zone 7 round is recommended as 1.0, the same as the M119A1 Zone 8 round.

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
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4. TITLE (and Subtitle) TEKEDIT - AN ENHANCED EDITOR FOR DIRECT VIEW STORAGE TUBE (DVST) GRAPHICS DISPLAY DEVICES		5. TYPE OF REPORT & PERIOD COVERED	
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7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(*)	
Mark Johnson			
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An overview and functional descript	tion of an editor	for host files using Direct	
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is an editor designed to augment a files using a graphics terminal as			
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White Layers Erosion Gun Barrels

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Specimens containing white layers were taken from the bore surface of the unplated and chrome plated fired gun tubes. These were examined metallographically and the presence of various "white layers" was established. The chemical and structural nature of these layers was determined by Auger/ESCA and x-ray diffraction techniques. The outermost white layer contained up to seven percent carbon and was identified as cementite - Fe₃C. The subsequent white layers had approximately one percent carbon and were identified as high carbon (CONT'D ON REVERSE)

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- 7. AUTHOR(S) (CONT'D)
 - J. D. Venables Martin Marietta Research Laboratory Baltimore, MD
- 20. ABSTRACT (CONT'D)

austenite. The significance of these results is discussed in terms of solution and diffusion of carbon from burnt propellant gases into iron during firing. The carbonaceous gases from the burnt propellant are responsible for the formation of white layers and are the cause of erosion and cracking in the bore surface. During heating and cooling of fired gun barrels, stresses are generated by the differences in the coefficient of expansion and volume changes associated with cementite, austenite, and matrix metal phases. Cracks are produced in the white layer and are propagated in the substrate steel matrix. The high carbon-containing phases are lower melting than steel. These molten phases are eroded away by the sweeping hot propellant gases, thereby eroding the bore surface of the gun barrel. These and other results are discussed in terms of their effects on erosion and wear in the gun barrel bore surfaces.

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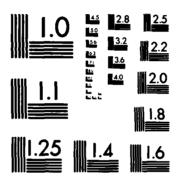
High Modulus Graphite/Epoxy

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A design and a manufacturing process are presented for a twenty-foot long anode to be used in the chrome plating of large caliber gun tubes. This anode provides ease in handling because of lighter weight yet maintains excellent stiffness properties. Considerable cost savings are anticipated by elimination of rework of gun tubes.

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